Micrometeoroid from MISSE Examined to Understand the Effects of the Space Environment on Space Suit

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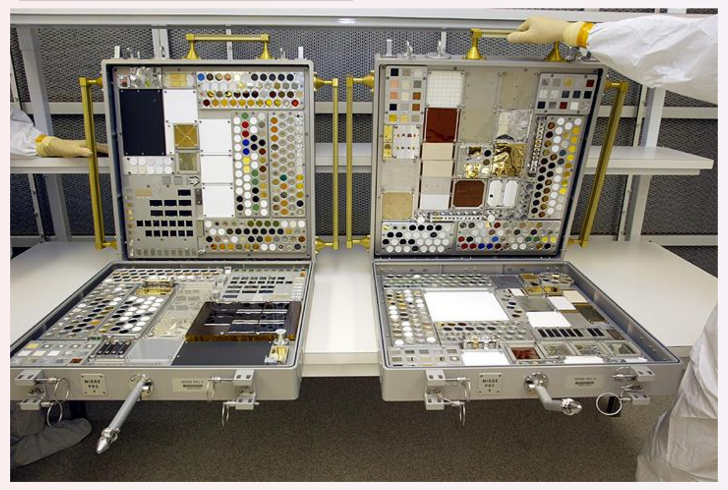
Overview of SUSpECS on MISSE-6

MISSE-6 is just one part of the MISSE project that aims to subject various materials to the space environment and document the effects in a controlled setting [1]. In order to do this the MISSE-6 samples were compiled, launched into space, suspended off of the International space station for 18 months, and then returned to Earth in pristine condition for analysis. The Utah State University SUSpECS project was a unique student experiment on MISSE-6 [3].

MISSE-6 Time Line

1/2005	Sample selection completed
12/2005	PEC's completed and tested for flight
3/2008	Launch on Space Shuttle ISS-123
9/2009	Return of samples from space



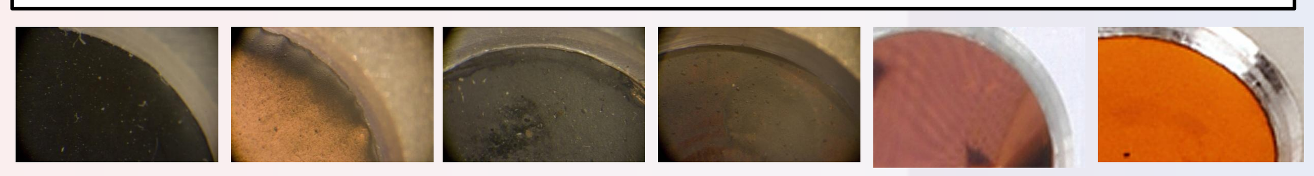
SUSpECS Objective

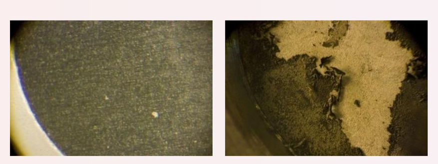
The purpose of SUSpECS is to characterize the performance of prospective spacecraft materials when subjected to the synergistic effects of the space environment, enabling more durable spacecraft assembly.

Figure: MISSE-6 A and B sample containers prepared for flight.

Pre- and Post- Flight Comparisons

Optical microscopy and normal specular reflectance of pre- and post-flight samples are compared to assess on-flight degradation.





Photographs comparing pre- and post-flight samples from SUSpECS II with ram exposure (Black Kapton 100XC, Acquadag, Kapton HN and Ag coated Mylar) and from SUSpECS III with wake exposure (Ag). Note the full AO (atomic oxygen) oxidation of the Ag coated Mylar sample and the UV yellowing of the polymer [2].

Future Work

Work on analysis of the effects of space environment exposure on the 168 samples has only begun. Measurements of optical and electron microscopy, reflectivity, FTIR, emissivity, mass loss, electron-, ion- and photon-induced electron emission, photoyield, AES, photoemission, and variable angle UV/VIS/NIR reflectivity will continue. Work will also progress in collaboration with the AEDC space simulation facility to understand the origins of these effects and quantify their impacts.

References/Acknowledgements

(1) JR Dennison, Amberly Evans, Danielle Fullmer, and Joshua L. Hodges, "Charge Enhanced Contamination and Environmental Degradation of MISSE-6 SUSpECS Materials," accepted for publication in IEEE Trans. on Plasma Sci., 40(2), 254-261 (2012). DOI: 10.1109/TPS.2011.2178104

(2) JR Dennison, John Prebola, Amberly Evans, Danielle Fullmer, Joshua L. Hodges, Dustin H. Crider and Daniel S. Crews, "Comparison of Flight and Ground Tests of Environmental Degradation of MISSE-6 SUSpECS Materials," Proceedings of the 11th Spacecraft Charging Technology Conference, (Albuquerque, NM, September 20-24, 2010), 12 pp.

(3) J.R. Dennison, Joshua L. Hodges, J. Duce, and Amberly Evans, "Flight Experiments on the Effects of Contamination on Electron Emission of Materials," Paper Number: AIAA-2009-3641, Proceedings of the 1st AIAA Atmospheric and Space Environments Conference, 2009.

(4) Material International Space Station Experiment (MISSE), Mar. 24, 2005. [Online]. Available: http://misse1.larc.nasa.gov/

(5) D. Hastings and H. Garrett, Spacecraft–Environment Interactions. Cambridge, U.K.: Cambridge Univ. Press, 1996.

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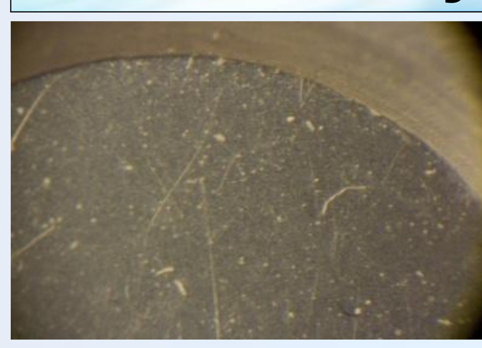
Abstract

Samples that were part of the Materials International Space Station Experiment (MISSE) experienced varying effects whilst exposed to the space environment; perhaps the most intriguing effect was the crater created by a micrometeoroid impact into a thin film of Vapor Deposited Aluminum (VDA) coated Mylar. Approximately 180 samples of various materials used in space-component design were flown on MISSE-6 and spent 18 months suspended off the side of the International Space Station. The Utah State University SUSpECS project was a unique student experiment that allowed for pre- and post-flight analysis of these material samples which were returned in pristine condition after exposure to the space environment. Despite micrometeoroids being a common occurrence, there is a significant lack of data pertaining to the effects of micrometeoroids on space components. Further examination of the micrometeoroid impact sample will allow us to determine the impact velocity, mass, and composition of the micrometeoroid and its influence on materials in space. Micrometeoroids pose a serious threat to space operations and in turn require constant observation. It is of particular interest to note that Mylar is a major component in the construction of astronaut suits; the knowledge gained from our evaluation of this meteoroid will allow us to determine the mass required to penetrate through a spacesuit.

Mylar with Micrometeoroid Impact



Before

After

Vapor Deposited Aluminum (VDA) coated Mylar

Sample and Impact Specifications:

Diameter of Exposed Mylar:	9mm
Diameter of Vaporized Region :	1.0 mm
Diameter of Spall volume:	1.5 mm
Diameter of Micrometeoroid:	5.3×10^{-1} mm
Thickness of Mylar Sample:	1.3×10^{-1} mm
Volume of Micrometeoroid:	7.7×10^{-5} cm^3
Density of Micrometeoroid:	3.5 gm/cm^3
Mass of Micrometeoroid:	2.7×10^{-4} gm

The VDA coated Mylar sample underwent vast changes in composition whilst in the ISS environment, beyond just the impact of the micrometeoroid. The most obvious would be the removal of VDA by Atomic Oxygen, exposing the underlying Mylar. Another is the yellowing of the initially white Mylar due to extensive UV exposure. Also evident is the degradation of the Mylar, again, due to Atomic Oxygen 4.

The estimated size of the micrometeoroid is found by matching the kinetic energy to the energy required to vaporize a hole of the observed size.

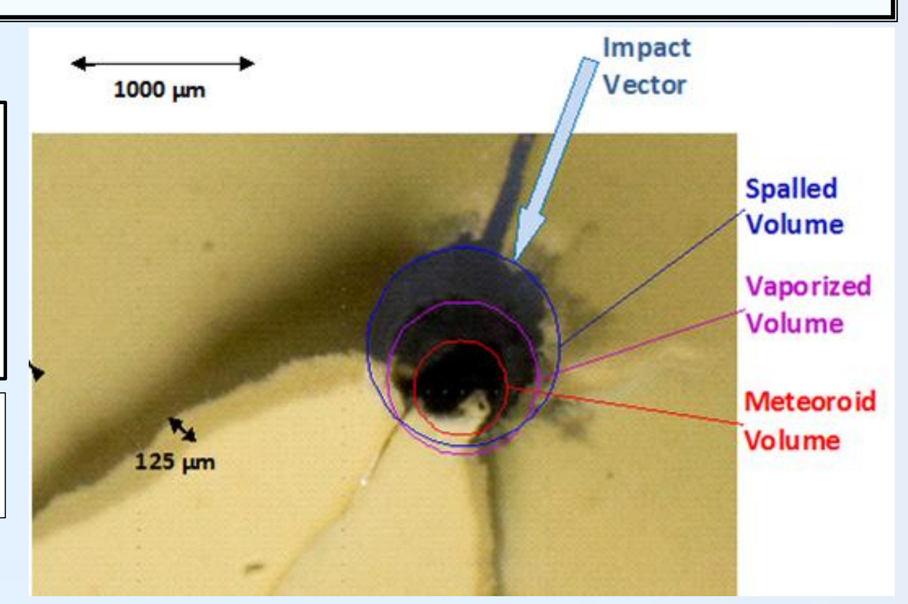


Figure: (Right) Rough, approximate projections of the damage due to the micrometeoroid impact.

Penetrating a Spacesuit

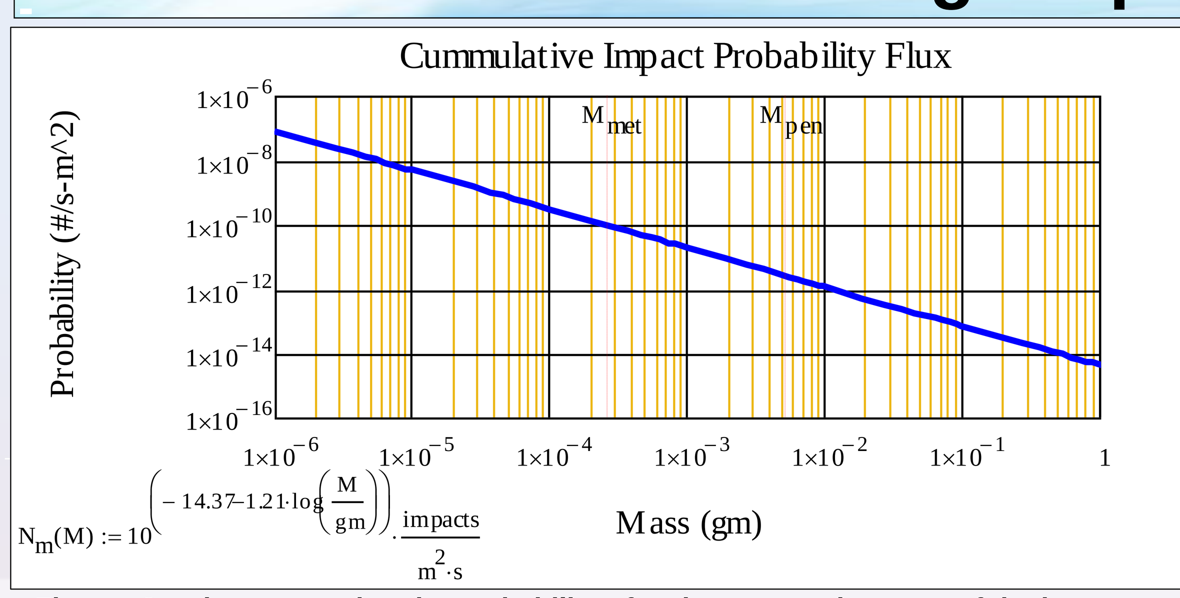


Figure: Graph representing the probability of an impact vs. the mass of the impact ejecta.

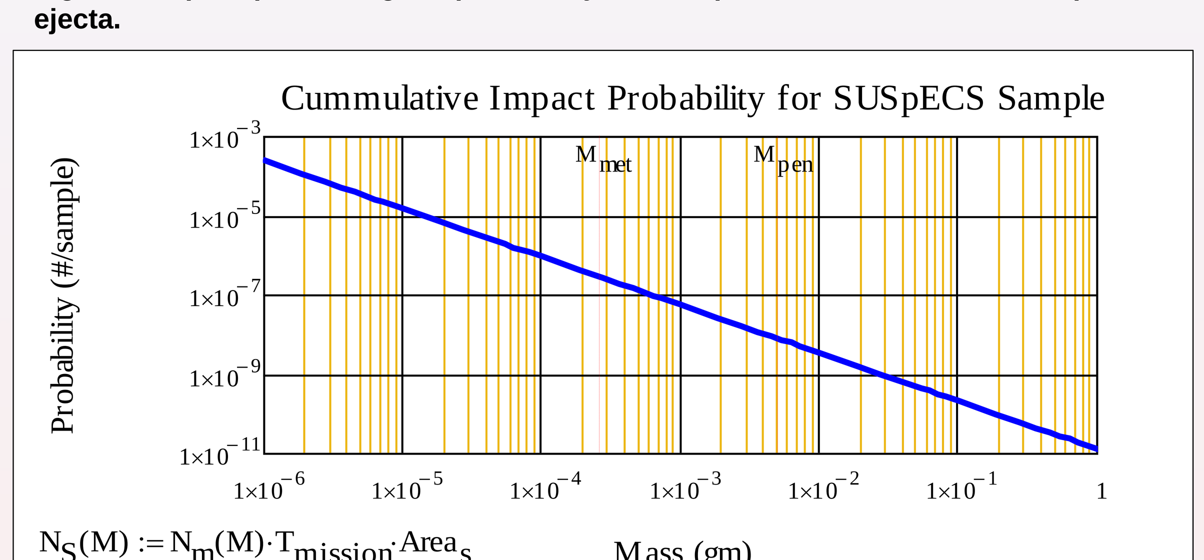


Figure: Graph representing the probability of an impact with a SUSpECS sample vs the mass of the impact ejecta.

Mass of a Penetrating Micrometeoroid:

Based on a 500 µm thick spacesuit, on typical meteoroid density and an observed relation for crater diameter and depth the minimum mass required to penetrate and ultimately kill an astronaut would be approximately 0.7 g [5].

Spacesuit Thickness:

A typical spacesuit has approximately seven 50 µm Mylar layers, one 50 µm Beta Cloth layer, and two other 50 µm layers totaling the suit's thickness at 500 µm [5].

Modern astronaut spacesuits are designed with a dual-layer system containing bumper plates to protect the wearer from supervelocity impact by foreign objects. This additional space allows for the compression of the space suits to lessen the force of the impact [5].

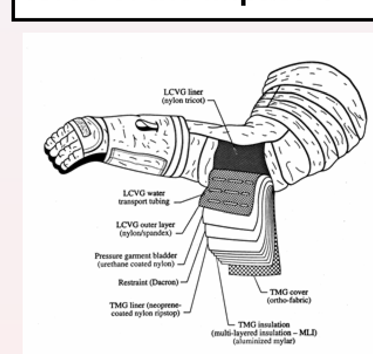
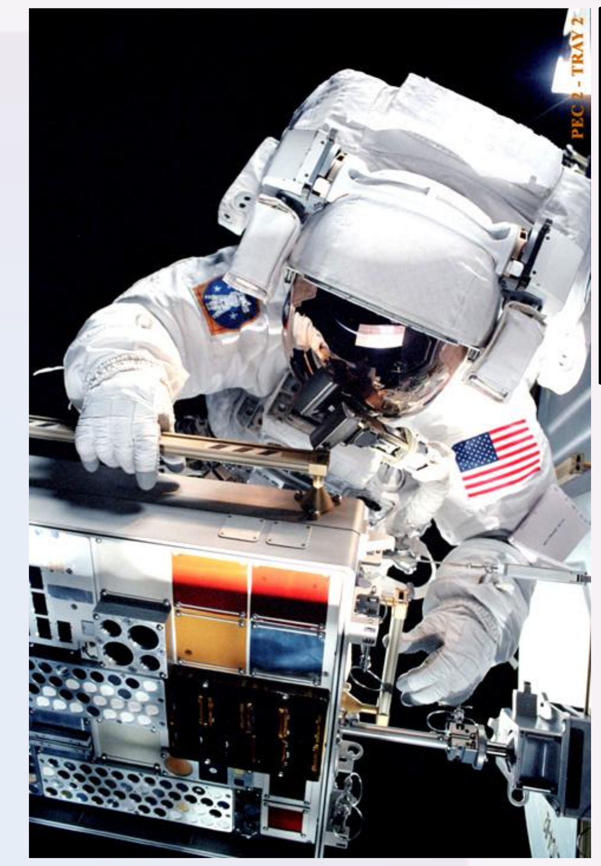
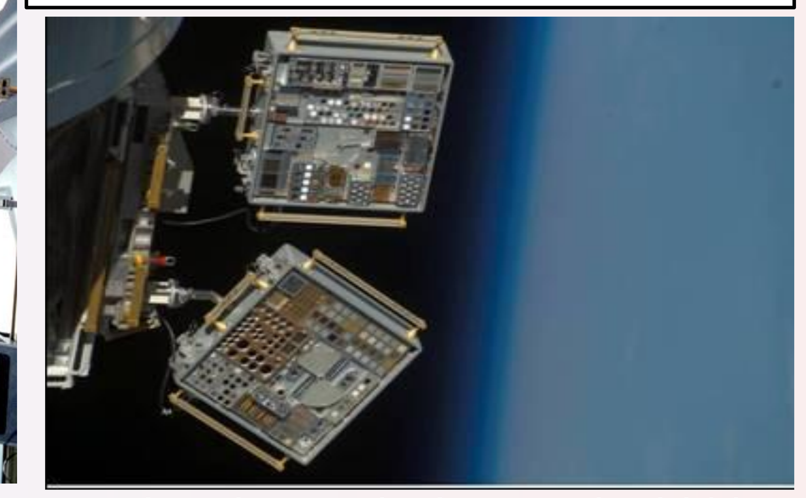


Figure: (Left) Layers of an astronaut's spacesuit, designed to protect against micrometeoroid impact.

Space Environment Exposure



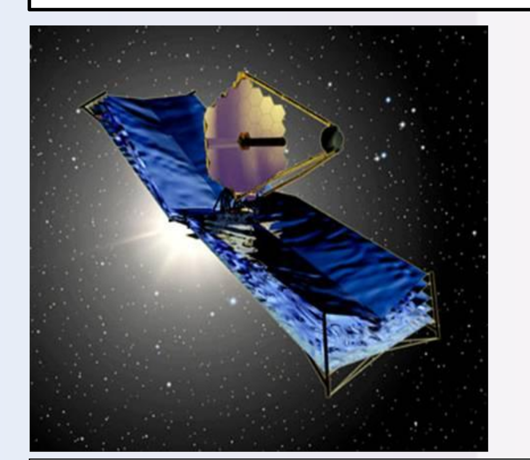
The ISS environment ranges in temperatures from approximately 40 K to 300 K. It is also a high plasma environment that causes the gas atoms to become ionized that leads to charging of surfaces in space. The direct UV light exposure combined with the atomic oxygen makes the ISS environment highly reactive leading to chemical erosion and oxidation of the materials.



Figures: (Above) Astronaut attaching MISSE-6 samples to the International Space Station. (Right) MISSE-6 samples, including SUSpECS, orbiting Earth suspended from the International Space Station.

Applications

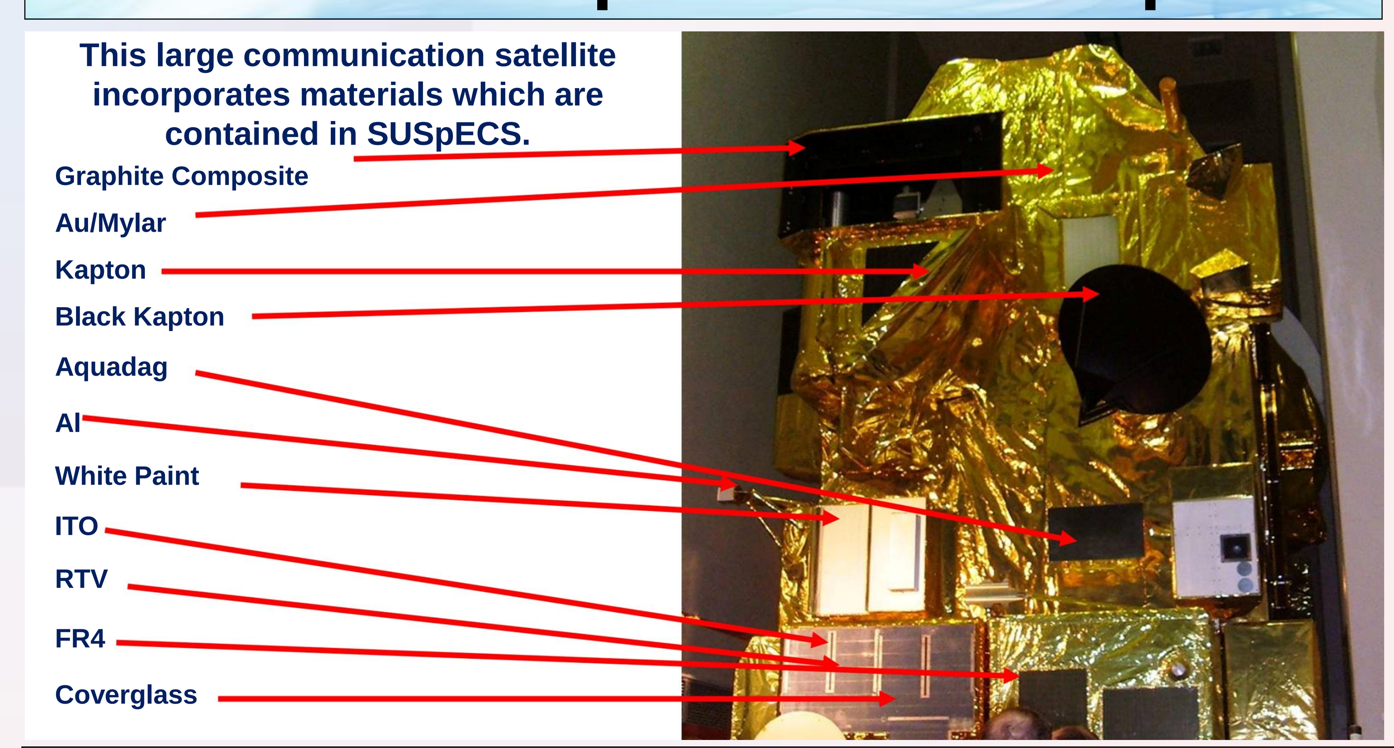
Material degradation in the space environment is a highly relevant study today. The most common application is the construction of spacecrafts and satellites (see figure of communication satellite below that identifies many common such materials that were flown on SUSpECS). An example of the application of such knowledge is the James Webb Space Telescope (JWST), shown below. The JWST is scheduled for launch in 2014 to replace the Hubble Telescope. This sensitive optical equipment on a massive platform the size of a tennis court will be launched further into the vastly unknown space environment than any permanent equipment thus far with an operational lifetime measured in decades. It therefore requires careful consideration in choice of materials for maximum time before erosion renders it useless.



The USU Materials Physics Group has worked on materials testing of JWST materials for the last 6 years. Tests were done with lab simulations of the space environment and with exposure on MISSE[3]. SUSpECS samples include JWST heat shield materials, cable insulation, structural composites and optical materials. Our tests will determine if changes in these materials due to space environment interactions will lead to dramatic changes in the operating temperature of JWST and its ability to take state of the art images to test our theories of the origins of the universe [1].

MISSE-6 SUSpECS Test Samples

This large communication satellite incorporates materials which are contained in SUSpECS.



SUSpECS Sample Sources

- Wide array of common spacecraft materials (see above).
- Basic materials and key contaminants of ISS solar arrays and structure.
- Materials from CRRES satellite designed to study environment-induced charging.
- Materials used in Floating Potential Measurement Unit plasma probe for ISS.
- Critical thermal control and optical materials for SDL GIFTS payloads.
- Composite and ceramic materials of the ATK Thermal Protection and Lightweight Structure Systems.
- James Web Space Telescope Insulator Sample Charging Tests.
- Solar Probe Mission Heat Shield Insulator Samples tests.